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METHOD, DEVICE, AND USE THEREOF FOR OPERATING A MOTOR VEHICLE

[0002] The invention relates to a method, a device, and use thereof for operating a motor vehicle having a drive motor and a transmission in the drive train.

[0003] According to Figure 1, a vehicle **1** has a drive unit **2**, such as a motor or an internal combustion engine. A torque transmission system **3** and a transmission **4** are also provided in the drive train of vehicle **1**. In this exemplary embodiment, torque transmission system **3** is situated in the power flux between the engine and the transmission, a drive torque of the engine being transmitted via torque transmission system **3** to transmission **4**, and from transmission **4** on the drive side to an output shaft **5** and to a downstream axle **6** and wheels **6a**.

[0004] Torque transmission system **3** is designed as a clutch, such as a friction clutch, multidisk clutch, magnetic particle clutch, or torque converter lockup clutch, for example, it being possible for the clutch to be a self-adjusting or wear-compensating clutch. Transmission **4** is an uninterrupted transmission (UT). According to the inventive concept the transmission may also be an automatic transmission (AT) which can be automatically shifted by least one actuator. An automatic transmission is further understood to mean an automated transmission that is shifted by tractive force interruption, and in which the shifting operation for the gear ratio is performed by actuation of at least one actuator.

[0005] Furthermore, an automatic transmission may be used as a UT, an automatic transmission essentially being a transmission without tractive force interruption and generally comprising planetary gear steps.

[0006] A continuously variable transmission, such as a conical disk belt-drive transmission, for example, may also be used. The automatic transmission may also be provided with a drive-side torque transmission system **3**, such as a clutch or friction clutch. Torque transmission system **3** may also be designed as a starting clutch, and/or a reverser clutch for

reversing the direction, and/or a safety clutch having a torque which may be transmitted in a targeted manner. Torque transmission system **3** may be a dry friction clutch, or a wet friction clutch that operates in a fluid, for example. The torque transmission system may also be a torque converter.

[0007] Torque transmission system **3** has a drive side **7** and an output side **8**, a torque being transmitted from drive side **7** to output side **8** by, for example, clutch disk **3a** being impinged on by force via pressure plate **3b**, disk spring **3c**, and release bearing **3e** as well as flywheel **3d**. For this impingement, release lever **20** is actuated by means of an actuating unit such as an actuator, for example.

[0008] Torque transmission system **3** is actuated by means of a control unit **13**, a controller, for example, which may include control electronics **13a** and actuator **13b**. In another advantageous design, actuator **13b** and control electronics **13a** may also be situated in two different assemblies, such as housings, for example.

[0009] Control unit **13** may contain the control and power electronics for actuating drive motor **12** of actuator **13b**. In this manner, for example, it is advantageously possible for the system to require as installation space only the space occupied by actuator **13b** together with the electronics. Actuator **13b** includes drive motor **12**, such as an electric motor, for example, electric motor **12** acting on a master cylinder **11** via a transmission, such as a worm gear, spur gear, crank gear, or threaded spindle gear. This effect on master cylinder **11** may be achieved directly or via a rod assembly.

[0010] The motion of the output section of actuator **13b**, such as master cylinder piston **11a**, for example, is detected by a clutch path sensor **14** which detects the position, location, speed, or acceleration of a variable which is proportional to the position or engaged position with respect to the speed or acceleration of the clutch. Master cylinder **11** is connected to slave cylinder **10** via a pressure medium line **9** such as a hydraulic line, for example. Output element **10a** of the slave cylinder is mechanically linked to release means **20**, a release lever, for example, so that a motion of output section **10a** of slave cylinder **10** causes release means **20** to likewise move or tilt in order to actuate the torque which is transmittable from clutch **3**.

[0011] Actuator **13b** for actuating the transmittable torque from torque transmission system **3** may be hydraulically actuatable; i.e., it may have a hydraulic sensor and slave cylinder. The pressure means may be a hydraulic fluid or a pneumatic medium, for example. The

hydraulic sensor cylinder may be actuated by an electric motor, it being possible to electrically actuate the electric motor provided as a drive element **12**. Besides an electric motor drive element, drive element **12** for actuator **13b** may also be another, for example hydraulically actuated, drive element. Magnetic actuators may also be used to adjust the position of an element.

[0012] For a friction clutch, the transmittable torque is actuated by pressing the friction linings of the clutch disk between flywheel **3d** and pressure plate **3b** in a targeted manner. Via the position of release means **20**, such as a release fork or central release element, for example, pressure plate **3b** may be impinged on by force with respect to the friction lining in a targeted manner, whereby pressure plate **3b** moves between two end positions and may be adjusted and fixed in place as desired. The one end position corresponds to a fully engaged clutch position, and the other end position corresponds to a fully disengaged clutch position. To actuate a transmittable torque which, for example, is less than the instantaneously applied engine torque, a position of pressure plate **3b**, for example, may be actuated which is situated in an intermediate region between the two end positions. The clutch may be fixed in place in this position by the targeted actuation of release means **20**. However, transmittable clutch torques may also be actuated which in a defined manner are higher than the instantaneously applied engine torques. In such a case, the instantaneously applied engine torques may be transmitted, the irregularities in torque in the drive train in the form of torque peaks, for example, being damped and/or insulated.

[0013] For actuating torque transmission system **3**, sensors are also used which at least intermittently monitor the relevant variables for the entire system and send the state variables, signals, and measured values necessary for actuation which are processed by the control unit, it being possible to provide and verify a signal connection to other electronic units, for example to engine electronics or electronics of an antilock braking system (ABS) or traction control system (TCS). The sensors detect rotational speeds, for example, such as wheel speeds, engine speeds, position of the load lever, throttle valve position, gear position of the transmission, shifting intention, and other vehicle-specific parameters.

[0014] Figure 1 shows that a throttle valve sensor **15**, an engine speed sensor **16**, and a tachometer **17** may be used to relay measured values or information to control unit **13**. The electronics assembly, such as a computer unit, for the control electronics **13a** processes the

system input variables and relays control signals to actuator **13b**.

[0015] The transmission is designed, for example, as a multistep variable-speed transmission, the transmission steps being changed by use of a shift lever **18**, or the transmission being actuated or operated by means of this shift lever **18**. In addition, at least one sensor **19b** is provided on shift lever **18** of the manual transmission which detects the shifting intention and/or gear position and relays same to control unit **13**. Sensor **19a** is linked to the transmission, and detects the instantaneous gear position and/or a shifting intention. The shifting intention may be recognized by use of at least one of two sensors **19a**, **19b**, by the fact that the sensor is a force sensor which detects the force acting on shift lever **18**. However, the sensor may also be designed as a path or position sensor, the control unit recognizing a shifting intention from the change of the position signal over time.

[0016] Control unit **13** has at least intermittent signal connection to all the sensors, and evaluates the sensor signals and system input variables in such a way that the control unit sends actuation or control commands to the at least one actuator **13b** as a function of the instantaneous operating point. Drive motor **12** for actuator **13b**, an electric motor, for example, receives from the control unit, which controls the clutch actuation, a manipulated variable as a function of measured values and/or system input variables and/or signals from the connected sensor system. To this end, a control program is implemented in control unit **13** as hardware and/or software which evaluates the incoming signals and computes or determines the output variables based on comparisons and/or functions and/or characteristic maps.

[0017] Control unit **13** advantageously has a torque determination unit which implements a gear position determination unit, a slip determination unit, and/or an operating state determination unit, or is connected by signals to at least one of these units. These units may be implemented as hardware and/or software, so that the incoming sensor signals may be used to determine the torque of drive unit **2** of vehicle **1** and the gear position of transmission **4**, as well as the slip present in the region of torque transmission system **3** and the instantaneous operating state of vehicle **1**. Based on the signals from sensors **19a** and **19b**, the gear position determination unit determines the instantaneously engaged gear. Sensors **19a**, **19b** are linked to the shift lever and/or to control means inside the transmission, such as a central shifting shaft or shifting rod, and detect same, such as the position and/or speed of these components. Furthermore, a load lever sensor **31** may be provided on load lever **30**, such as a gas pedal, for

example, which detects the position of the load lever. An additional sensor **32** may function as a no-load switch; i.e., when load lever **30** or the gas pedal is actuated this no-load switch **32** is turned on, and when load lever **30** is not actuated the no-load switch is turned off, thereby enabling digital information to be recognized concerning whether load lever **30** is actuated. Load lever sensor **31** detects the degree of actuation of load lever **30**.

[0018] Figure 1 shows, in addition to load lever **30** and the sensors connected thereto, a brake actuating element **40** for actuating the service brake or the parking brake, such as a brake pedal, hand brake lever, or a hand- or foot-actuated actuating element for the parking brake. At least one sensor **41** is situated on actuating element **40** and monitors the actuation thereof. Sensor **41** is designed as a digital sensor such as a switch, for example, which detects whether or not the brake actuating element **40** is actuated. By use of sensor **41** a signal device such as a brake light, for example, may be connected by signals, and signals that the brake is actuated. This may be carried out for both the service brake and the parking brake. However, sensor **41** may also be designed as an analog sensor, such a sensor, a potentiometer, for example, determining the degree of actuation of brake actuating element **41** [sic; **40**]. This sensor as well may be connected by signals to a signal device.

[0019] One embodiment of the present invention is described below, in which a suitable control is proposed for a vehicle drive train having a crankshaft starter generator.

[0020] Strategies for controlling a vehicle drive train are provided which include, for example, an internal combustion engine, a crankshaft starter generator between two clutches, and an automatic transmission (AT).

[0021] The advantages of using a starter generator lie, on the one hand, in the increased comfort for the driver (damping of torsional vibrations, among other factors), and on the other hand, in the possibility for energy recovery (recuperation).

[0022] One particularly advantageous system is the placement of the starter generator between two clutches on the crankshaft to enable the internal combustion engine to be decoupled from the output during the thrust phase in order to recover energy by electrical braking. This system is described below.

[0023] In this system, it is important that the driver does not feel a jolt when the internal combustion engine is started at the end of a recuperation phase. The same situation exists when the internal combustion engine must be turned on to increase the tractive force during a start-up

performed solely by the electric motor. This may be necessary, for example, for an uphill start or for a battery under slight load.

[0024] Meaningful criteria must be defined in order to decide when the internal combustion engine should be turned on during a start-up.

[0025] According to one refinement of the invention, the vehicle may be started, depending on the driver's intent, purely by electrical means, or with assistance from the internal combustion engine. The driver's intent may be directly ascertained by a number of ways. For example, depending on the position of a driving program switch, a decision may be made via the start mode as to how the start-up should be performed. For example, for an activated economy program the start-up may be purely electrical, and for an activated sport program the start-up may be carried out using the internal combustion engine, or also in combination with the electrical drive. It is also possible to select other combinations.

[0026] A further possibility is the evaluation of the accelerator pedal position. During an electrical start-up, the internal combustion engine could be turned on when, for example, a kickdown switch is actuated for longer than a specified time period. The internal combustion engine may also be turned on when, for example, the pedal position exceeds a given threshold, and/or an additional threshold is exceeded for longer than a specified time period. The internal combustion engine may also be activated when the change of the pedal position over time exceeds a specified positive value. Lastly, any given combination of the referenced, and additional, possibilities is conceivable.

[0027] Another refinement of the invention provides that the internal combustion engine is turned on during a start-up when, for example, the control system detects that the available tractive force does not correspond to the driver's intent. This may preferably be determined by comparing the longitudinal acceleration of the vehicle, which is computed, for example, based on the change in the wheel rotational speeds over time, to the assumed acceleration, which is computed based on the tractive force that is calculated with reference to the torques of the internal combustion engine, the electric motor, and the clutches. When, for example, the actual vehicle acceleration is less than the assumed acceleration, based on the computed tractive force, by more than a specified quantity for more than a certain period of time, starting of the internal combustion engine is initiated.

[0028] Within the scope of a further embodiment of the invention, the internal

combustion engine may be activated by targeted actuation of both clutches without appreciable loss of comfort for the driver. The concept of activating the engine after the transmission-side clutch is disengaged is unacceptable on account of the resulting tractive force interruption. A better approach, therefore, is to turn on the internal combustion engine after the transmission-side clutch has been moved into the sliding state in a targeted manner. During this phase the output is decoupled from the drive. Thus, the output torque may also be held at a level that is acceptable to the driver by means of the friction torque of the transmission-side clutch.

[0029] One possible sequence of the strategy according to the invention may be carried out as follows.

[0030] First, the "activation of the internal combustion engine" situation is recognized. If the transmission-side clutch is in the engaged state, the transmittable torque to the transmission-side clutch is reduced until the clutch goes into the sliding state. This reduction could be achieved by torque control as well as by path control of the actuating device for this clutch.

[0031] When the slip phase has definitely been reached (locking time, minimum slip), the internal combustion engine along with the electric motor may be turned on. This may be achieved by a controlled engagement of the engine-side clutch, for example by torque control, path control, or the like.

[0032] The slipping state at the transmission-side clutch should be maintained until the engine-side clutch has changed to the engaged state, and thus any resulting vibrations in the internal combustion engine and in the electric motor have sufficiently subsided.

[0033] The slip phase could be maintained by holding the output torque constant with slip monitoring. It is particularly advantageous when slip control is provided for the transmission-side clutch. The output torque is thus adjusted by the friction torque at this clutch, corresponding to the driver's intended torque. The amount of slip may be selected so that on the one hand unintended engagement is avoided, and on the other hand, the power loss at this clutch remains low.

[0034] When the slip phase has ended (see paragraph before last for the condition), the internal combustion engine and the electric motor are accelerated, the engagement of the transmission-side clutch being achieved by targeted coupling. The transmission-side clutch may thus be actuated corresponding to the coupling during a start-up or shifting operation for a vehicle with automatic clutch actuation.

[0035] This method according to the invention may preferably be used for both start-ups and at the end of recuperation phases.

[0036] Figure 2 schematically shows one possible system in which a starter generator is situated between two clutches. The direct current motors are designated by reference numerals M1 through M4. In addition, the main cylinder is designated by MC, the auxiliary cylinder by SC, and the concentrically situated auxiliary cylinder, by CSC.

[0037] A further embodiment of the present invention is described below, in which a pulse start, for example for vehicles having a starter generator with a slip clutch, is proposed.

[0038] There are various possible configurations for the use of a starter generator. One possible configuration is illustrated in Figure 3. In this case, the starter generator is situated between two clutches K1 and K2. Clutch K1 connects the starter generator to the internal combustion engine, and clutch K2 connects the starter generator to the transmission.

[0039] There are various driving situations, such as start-up by an electric motor, for example, in which clutch K2 transmits a torque, clutch K1 however being disengaged and the internal combustion engine not being activated. If the internal combustion engine is to be turned on in this situation, clutch K1 may be engaged to start the internal combustion engine.

[0040] When this engagement of the clutch occurs, the torque can now be controlled in such a way that the driver perceives little or no disturbances on the drive train. This is not easy to control by use of control instrumentation, in particular when the available actuation and signal accuracy are taken into account.

[0041] Consequently, according to the invention it is proposed to operate clutch K2 with slip, preferably during the start-up operation. Under the assumption that the slip is > 0 until the end of the start-up operation, it may thus be ensured that the changes in torque at the starter generator/internal combustion engine side do not act on the drive train.

[0042] According to one preferred refinement of the invention, one possible start-up operation may be carried out as follows:

[0043] 1. The internal combustion engine is idle, clutch K1 is disengaged, clutch K2 is engaged without slip, and the vehicle travels exclusively by means of the electric motor drive.

[0044] 2. Clutch K2 and the starter generator are actuated so that slight slip is established at K2 as smoothly as possible. The torque transmitted to K2

should be essentially the same as the previously drive torque delivered from the electric motor.

[0045] 3. The torque of the starter generator is increased, and at the same time clutch K1 is engaged. In this regard, clutch torque K1 must not be (significantly) greater than the additional torque of the starter generator. The engine is started.

[0046] The start-up operation may be modified for further optimization.

[0047] Alternatively, the starter generator may first be accelerated to a higher rotational speed, clutch K2 continuing to transmit a constant torque. Clutch K1 may then be engaged. The torque transmitted from clutch K1 may now be significantly greater than the additional torque of the starter generator. The starter generator is thereby braked, and the kinetic energy is transmitted from the starter generator to the internal combustion engine for the start-up operation. In this regard it is important that clutch K2 continues to be operated in slip mode, i.e., that the rotational speed of the starter generator does not fall below the transmission input rotational speed of the transmission.

[0048] Other possibilities are conceivable, such as when the starter generator is in recuperation mode. For this situation, it is crucial that clutch K2 is in slip mode.

[0049] The proposed control strategy may preferably be used in hybrid vehicles, vehicles with an electric transmission (ET), or the like.

[0050] Another embodiment of the present invention is described below, in which a suitable method is proposed for controlling preferably the engine-side clutch for a system having a starter generator, an internal combustion engine, a dual clutch, and an automatic transmission (AT).

[0051] It is an object of the invention to implement a method for actuating the engine-side clutch which enables the internal combustion engine to be comfortably shifted.

[0052] In one system having a starter generator, an internal combustion engine, a dual clutch, and an automatic transmission (AT) as shown in Figure 2, the engine-side clutch is used primarily to activate the internal combustion engine. Besides turning on the internal combustion engine when the vehicle is stopped for the purpose of starting up using the internal combustion engine and the starter generator, start-up of a traveling vehicle may also be necessary in the following situations:

- End of a recuperation phase (the driver actuates the gas pedal)
- A start-up performed initially solely by electric means may be assisted by the internal combustion engine, for example when the tractive force is not sufficient.

[0053] Other situations are also conceivable in which turning on the internal combustion engine is advantageous.

[0054] The transmission-side clutch may remain in the engaged state during start-up to keep energy losses low. Otherwise, the internal combustion engine may also be turned on when the transmission-side clutch is in slip mode.

[0055] For activating or turning on the internal combustion engine, the engine-side clutch may now be actuated by torque control or path control (path of the actuator), in which the friction torque transmittable by this clutch preferably increases monotonally or in a similar manner. In this case, however, the transition from the sliding to the engaged state may be very uncomfortable. This may be due to the fact that the clutch torque being transmitted has a discontinuous progression, such as from a large negative value, for example 100 Nm, to a small value which may be positive or negative, depending on whether or not the internal combustion engine has already produced torque. This may be manifested by a strong, for example positive, jolt.

[0056] This may be seen from Figure 4, which shows three diagrams. The vehicle acceleration afzg over time is represented in the upper diagram. The jolt is indicated by the minimum of the curve. A jolt also occurs when a vehicle with a manual transmission is push-started.

[0057] In addition, the lower two diagrams in Figure 4 illustrate the curves for the rotational speeds of the internal combustion engine, the transmission, and the asynchronous motor, as well as the curves for the torques of the internal combustion engine, the engine-side clutch, the transmission-side clutch, and the asynchronous motor over time.

[0058] According to the invention, preferably the engine-side clutch is actuated ("opening up the engine") so that the described jolt is greatly reduced. A method which enables this is described below:

[0059] 1. The decision to turn on the internal combustion engine is made by the control for the system.

[0060] 2. The (positive) torque of the starter generator is maintained for a start-up. When the recuperation phase has ended, the torque of the starter generator may either be increased to a positive value, for example by a ramp function or another comfortable transition function, or it may initially be left at a negative value.

[0061] 3. A friction torque may then be formed at the engine-side clutch by means of path control or torque control, the friction torque overcoming the drag torque of the internal combustion engine and allowing the rotational speed of the internal combustion engine to increase, which is referred to as "opening up the engine."

a) For a start-up, the maximum gradient of the friction torque may be selected such that the vehicle acceleration does not decrease abruptly.

b) When the recuperation phase has ended, the torque of the starter generator may be selected by compensation for the clutch torque in such a way that the resulting vehicle acceleration remains constant at a positive or negative value.

[0062] 4. Before the rotational speed of the internal combustion engine reaches the rotational speed of the starter generator, the transmittable torque of the clutch may be reduced again, preferably to a value of 0 Nm, to achieve a) no engagement or b) engagement with very little jolt, at equal rotational speed. The start of reduction of the friction torque may preferably be determined as follows:

- The rotational speed of the internal combustion engine exceeds a rotational speed threshold (for example, 300 rpm).
- The slip rotational speed n_{VM}-n_{SG} exceeds a threshold (for example, -500 rpm).
- One of the first two conditions is met, and the gradient of the engine rotational speed (or of the slip rotational speed) exceeds a threshold.
- The actuator path reaches a threshold ("opening point").
- A combination of the preceding conditions is met.

The reduction of the friction torque may be carried out as described under

3a) and 3b) (gradient limitation or with torque compensation by the starter generator).

[0063] 5. If no engagement occurs during step 4. (variant 4a), the clutch cannot be re-engaged until the rotational speed of the internal combustion engine has exceeded the rotational speed of the starter generator by a certain value, or until it is ensured, based on an examination of the gradient, for example, that this situation will occur.

[0064] 6. A clutch strategy as used in vehicles having electronic clutch management (ECM) or an automatic transmission (AT) may now be carried out. For coupling, the friction torque is modified via path control or torque control, and the internal combustion engine, already started, may likewise be controlled so that the attrition of the rotational speeds is comfortably configured.

[0065] The proposed method, in particular for actuating the engine-side clutch, may also be suitably modified for further optimization. Turning on the internal combustion engine with the so-called opening up, with a slight jolt, can be seen in Figure 5.

[0066] Three diagrams are shown in Figure 5. The vehicle acceleration afzg over time is represented in the upper diagram. The slight jolt is indicated by the minimum of the curve. In addition, the lower two diagrams in Figure 5 illustrate the curves for the rotational speeds of the internal combustion engine, the transmission, and the asynchronous motor, as well as the curves for the torques of the internal combustion engine, the engine-side clutch, the transmission-side clutch, and the asynchronous motor over time.

[0067] To enable the described actuation of the clutch to be suitably carried out, it is advantageous to know the friction torque as a function of the actuator path.

[0068] A further aspect of the invention is that the "opening-up point," defined as the path of the actuating device, is used as an indication for this function.

[0069] This opening-up point is determined by observing the engine rotational speed for the described start-up operation. When the engine rotational speed reaches a specific threshold value greater than 0 rpm, for example n = 100 rpm or the like, the instantaneous position of the control unit is ascertained, and the opening-up point is thus determined. This threshold value may also be the smallest rotational speed value or the like that is quantifiable by the particular

measurement method.

[0070] The value of the point thus determined may preferably be stored in a volatile memory or the like for the further progression of the driving cycle, and/or in a non-volatile memory for subsequent driving cycles. In a further control process for the clutch, the specifications for the actuating device for the clutch may now be referenced to this point. In this manner, for example after the opening-up point is reached, the actuator path as mentioned in step 4 may be cancelled. It is also possible to lower the adjustment speed shortly before the point is reached.

[0071] Since the opening-up point is very dependent on the drag torque of the engine and thus the temperature, a value for the opening-up point which is corrected by a temperature factor or offset may be stored in the memory.

[0072] A further possible embodiment of the present invention is described below in which, for example, the rotational speed information for a starter generator is preferably used for controlling an automatic transmission (AT).

[0073] One object of the present invention is to improve the control with respect to comfort, availability, and safety of an automatic transmission (AT) by use of rotational speed information from a starter generator.

[0074] In particular for an AT system, knowledge of the transmission input rotational speed is of great importance. For this reason, in many cases a sensor is provided directly on the transmission to determine the rotational speed thereof. The sensor may be omitted, out of cost considerations, for example, and the transmission input rotational speed may be determined from the output rotational speed and the instantaneous gear ratio present.

[0075] The rotational speed of the rotor may be necessary for controlling a starter generator situated, for example, between the internal combustion engine and the transmission. The starter generator may be separated from the internal combustion engine and the transmission by one or two clutches.

[0076] In one system having a clutch between the starter generator and the transmission, the rotational speed of the starter generator is identical to the rotational speed of the internal combustion engine. An additional rotational speed sensor (compared to a vehicle without a starter generator) is therefore not absolutely necessary.

[0077] For a system having a clutch between the starter generator and the internal

combustion engine, the rotational speed of the starter generator is identical to the rotational speed of the transmission input. An additional rotational speed sensor is therefore only conditionally necessary.

[0078] For a system having a dual clutch between the starter generator and the transmission, in some situations the rotational speed of the starter generator is identical to the rotational speed of the internal combustion engine, and in some situations is identical to the rotational speed of the transmission input. An additional rotational speed sensor, therefore, is absolutely necessary.

[0079] For a four-quadrant drive of the starter generator, direction recognition may also be advantageous.

[0080] According to the invention, the information on the rotational speed and possibly the rotational direction, supplied by the starter generator, may be used for the AT control. The comfort, safety, and availability of the system may be improved in this manner. Primarily (but not exclusively) a system having a dual clutch is considered, as illustrated by way of example in Figure 2.

[0081] In the following strategies, the rotational speed information from the starter generator may preferably be used:

[0082] 1. For an unexpected difference in rotational speeds between the internal combustion engine and the starter generator, and/or between the starter generator and the wheel speeds, the engine-side and/or transmission-side clutch, preferably with consideration for the instantaneous gear ratio, may be further engaged to reduce slip.

[0083] 2. For a shifting operation having an engaged clutch between the starter generator and the transmission input, the start and end times for the synchronization process may be detected. This may preferably be used for controlling the shift actuator, adaptation of the synchronization points, and even for an initial start-up, or the like.

[0084] 3. For an engaged clutch between the starter generator and the transmission input, the gear engaged in the transmission may be determined by use of wheel speed information, and thus may be used to check the plausibility of the position of the transmission control unit.

[0085] 4. For an engaged clutch between the starter generator and the transmission input, the signals from the wheel speed sensors may be checked for plausibility and/or may be replaced. If, for example, the signal from a wheel speed sensor has failed, for an engaged, known gear the missing wheel speed may be determined from the rotational speed signal from the starter generator.

[0086] 5. If the wheel speed sensor fails, the operation may switch to emergency mode, in which the transmission-side clutch is always kept engaged. Provided the transmission is in neutral, the vehicle speed can then be computed from the rotational speed of the starter generator and the instantaneous gear ratio.

[0087] 6. Using direction recognition for the starter generator, for a purely electrical start-up in which the engine-side clutch is disengaged and the transmission-side clutch is engaged, a check may be made as to whether the vehicle has been set in motion according to the driver's intent, and whether a contrary action should be taken. If, for example, for a start-up in a forward gear it is determined that the vehicle is rolling backward, a decision may be made for an uphill start. As a response, the current flow to the electrical motor may preferably be increased to increase the drive torque in the driver's intended direction (hill-holder).

[0088] 7. The rotational speed information for the starter generator, in conjunction with the engine and/or wheel speed information, may be used to estimate the temperature of the engine-side and/or the transmission-side clutch. To this end, a temperature model, for example, may be used such as that already employed in vehicles having electronic clutch management (ECM) or an automatic transmission (AT).

[0089] A further embodiment of the present invention is described below, in which a vehicle is proposed that has a hybrid system or ESG system with the same starting characteristics as for an internal combustion engine and electric motor start-up.

[0090] In this manner, regardless of which type of prime mover is used for starting, a reproducible sense of start-up is communicated to the driver.

[0091] In another possible strategy, for a start-up control, for example, a clutch torque progression dependent on the pedal value is specified, in particular for a start-up using the internal combustion engine, or, alternatively, the same torque progression for an electric motor start-up.

[0092] For electronic clutch management (ECM) or an automatic transmission (AT), a start-up strategy may be used in which the clutch slip is reduced in every case, thereby ensuring a smooth transition from slip to engagement, and avoiding rotational speed or torque vibrations in the internal combustion engine and the drive train.

[0093] This strategy may be advantageously used to achieve a reproducible acceleration response during start-up.

[0094] Furthermore, the object, also for a hybrid drive system in which the start-up may be performed by an internal combustion engine as well as an electric motor, is to develop strategies which provide a reproducible start-up response for the driver, regardless of the motor selected.

[0095] This is particularly true for start-ups with the gas pedal actuated. The referenced clutch control produces creep in the activated no-load switch (accelerator pedal not actuated), which for both motors may be similarly implemented as time-dependent torque formation.

[0096] Numerous possible combinations exist. For example, for an internal combustion engine start-up the same strategy may be used as for the ECM/AT system, the clutch preferably being engaged independently of the rotational speed.

[0097] For a combined start-up using the internal combustion engine and the electric motor, the drive train torque may also be formed by the rotational speed-dependent engagement of the start-up clutch. Coordination of the two drive motors for implementing the driver's intent takes place in a higher-level coordinator. Thus, from the standpoint of the start-up response, there is no difference from a start-up performed solely by the internal combustion engine. The clutch control processes the added torque from the internal combustion engine and electric motor.

[0098] For a purely electric motor start-up, the start-up clutch may be engaged from the beginning, and the drive train torque may be formed solely by the electric motor.

[0099] A specialized subprogram is contained in the control system which simulates engine runaway on the basis of the driver's intent. Based on this information and the start-up

parameters (start-up characteristic map) stored in the control system, the corresponding clutch setpoint torque is computed, which for a purely electric motor start-up is then adjusted not at the clutch, which is engaged, but at the electric motor.

[0100] Figure 6 schematically illustrates the networking of the various subprograms in the control software for a corresponding vehicle. There is a higher-level drive train coordinator which is responsible for specifying the gears, apportioning between the two drive motors, etc. This coordinator supplies the controls for both drive motors and for the transmission and clutch with information on the setpoint gear, setpoint torques, etc.

[0101] The additional subprogram accesses the same application parameters for the start-up response of the vehicle as for the clutch control. The torque resulting from the simulation is then sent, either directly or via the coordinator, for example, to the electric motor control and is processed there.

[0102] In principle, each of these subprograms may be composed of several modules. All of the subprogams in Figure 6 may be present in a control unit, or may be distributed over multiple control units which communicate with one another. It is also possible to divide the submodules of a subprogram among various control units, i.e., for the control units to "divide up the work."

[0103] It is important that the functions assigned to the subprograms are present in the overall control system, which results in many different embodiment possibilities.

[0104] For example, other implementation or calculation possibilities for the setpoint torque may be used instead of the simulation. A fixed characteristic curve or a simple dynamic computation model, for example, may be stored, the parameters of which may be calculated offline. To this end, preferably the corresponding application parameters from the clutch control may be used.

[0105] Figure 7 illustrates one possible program sequence in the subprogram for simulating the internal combustion engine, the program sequence being provided for computing the electric motor start-up torque.

[0106] As an entry requirement, a query may be made as to whether a purely electric motor start-up has occurred at all, or is imminent.

[0107] Based on the driver's intent (pedal value or no-load switch), a decision is then made whether to use the idle rotational speed of the electric motor for the virtual rotational speed

thereof ($n_{VM\_virt} = n_{VM\_idle}$ ensuring the initial condition for the subsequent start-up if the pedal has not been pressed), or whether a calculation of the electric motor torque matched to the clutch control is made during start-up.

[0108] For simulation of the internal combustion engine, the virtual torque thereof may preferably be computed using the engine characteristic map:

$$M_{VM\_virt} = M_{VM}\,(n_{VM\_virt}, \textit{pedal value})$$

and the new virtual rotational speed may also be computed by integrating the motion equation:

$$n_{VM\_virt\_old} = n_{VM\_virt}$$

$$n_{VM\_virt} = n_{VM\_virt\_old} + \frac{30 M_{VM\_virt}}{\pi \cdot J_{VM}} \Delta T$$

[0109] These data are then used for computing the virtual clutch setpoint torque corresponding to the start-up characteristic map for the clutch control:

$$M_{R\_setpoint\_virt} = M_{start\text{-}up}\,(n_{VM\_virt}, n_{transmission})$$

[0110] The electric motor control system receives the value of the virtual clutch setpoint torque as the setpoint specification for the electric motor. Thus, for the electric motor start-up the vehicle responds in the same way as for an internal combustion engine start-up with the same pedal value.

[0111] The central idea for this simulation is "What would happen if the internal combustion engine were used for the start-up?" Other information channels, such as information from the engine control of the internal combustion engine, or other equations such as another integration algorithm for the motion, for example, may be used in computing the virtual torque and the virtual rotational speed of the internal combustion engine.

[0112] The concept according to the invention may preferably be used for a vehicle having a hybrid drive. Furthermore, the start-up strategy may be used for electrical start-ups using a starter generator, or for vehicles having an electric transmission (ET).

[0113] The claim filed with the application represents suggested wording, without prejudice to obtaining further patent protection. The applicant reserves the right to claim additional feature combinations thus far disclosed only in the description and/or drawing.

[0114] Since advantageous refinements with respect to the prior art on the priority date may constitute separate, independent inventions, the applicant reserves the right to make such refinements the subject of dependent and/or independent claims or divisional declarations. Such refinements may also constitute independent inventions having a form that is independent of the subject matter of the preceding embodiments.

[0115] The exemplary embodiments are not construed so as to limit the invention. Rather, within the scope of the present disclosure, numerous variations and modifications are possible, in particular variants, elements, and combinations and/or materials which, for example, may be inferred, with respect to achieving the object, by one skilled in the art by a combination or variation of individual features, elements, or method steps in conjunction with those described in the general description and embodiments and in the claim, and contained in the drawing, and which by combinable features result in a new subject or new method steps or method step sequences, also to the extent to which they relate to production, testing, and operating methods.